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DEC 75 J R BLOOMFIELD, C P GRAF, K GRAFFUNDER DAAK02-75-C-0055

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20. ABSTRACT (CONTINUE ON REVERSE SIDE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER)

In this study of visual factors in target disruption, the objective was to determine (1) the relationship between variations in the properties of disruptors, and ~~to determine~~ (2) the effectiveness of those disruptors in concealing military targets from visual detection when they are placed in various classes of natural background. A disruptor is an umbrella-like object attached to a target ~~in such a way~~ so as to obscure part of it.

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Four background scenes were selected. They were low, oblique, aerial views of Virginia, Minnesota in the Fall, Minnesota in the Winter, and Nebraska. One of four military targets, a helicopter, tank, howitzer or truck, was placed in turn in each scene. A series of disruptive camouflage treatments was tested using the target-background imagery. Both the targets and disruptors were photographically embedded in the original scene.

Two experiments were carried out. In the first, 155 camouflaged conditions were compared with 16 uncamouflaged pictures. Variations were made in the color, size, number and location on the target of disruptors. At least 10 observers searched each of the 171 tested scenes. Search time and detection performance were recorded. In the second experiment, the 16 uncamouflaged target pictures were used with 16 of the more successful disruptor combinations. While each observer searched for the targets his/her eye movements were monitored with an oculometer. This device computes eye position by comparing the position of a virtual image of an infrared source with the position of the center of the pupil. Eye movement patterns and detection performance were recorded. In both experiments, a vision test was used to ensure that all observers had a near-visual score of at least 20/20 and normal color vision. All observers also took part in a hidden figures test. There were 258 observers in the main experiment, and 24 in the oculometer study.

The result of comparing the 155 camouflaged treatments with the 16 uncamouflaged conditions was that the search time was significantly increased in 46 cases. The most successful camouflage occurred for all four targets in the Minnesota Fall scene, and for the howitzer in all four scenes. The increase in difficulty for these successful conditions produced search times that were two to four times as large as those obtained with the equivalent uncamouflaged targets.

Test results indicate that:

Targets are harder to find where the mean contrast level of the ground is close in value to the mean contrast level of the foliage, and where the variability around the mean contrast level is high; Small targets are easier to hide; and it is easier to obscure the outline of an elongated target than ~~that of~~ a compact target. (cont on p 1473)

Where the ground is relatively dark, the basic color of the disruptor should be as dark as the ground. The effectiveness of the disruptor will be increased by adding to it colors that are even darker. For scenes in which the ground is relatively light in color, the disruptors may be basically colored like the foliage or they may include lighter colors that match the ground.

Changes in disruptor location did not produce a clear effect. Increases in disruptor size led to modest increases in search time. However, a much bigger effect was produced by increasing the number of disruptors used.

The oculometer study showed that when successful camouflage is used, the observers spread their eye fixations over a much wider area of the background scene. Such camouflage produces identification problems, but it clearly makes the target much harder to detect as well.

No systematic correlation was found between performance on the hidden figures test and the search task.

(Cont of p1473B)

To reduce the probability of a target being detected or of increasing the time required to detect it, the following suggestions are made. ~~First,~~ the target should be placed in an area with relatively dark ground and foliage, where ~~the~~ ground and foliage are heterogeneous rather than homogenous. ~~Next,~~ the color used as the basis for the disruptive material should be as dark as the ground. ~~The~~ disruptors should also have other colors which are even darker. It ~~will~~ be most effective to use several small disruptors, placed to break up the outline of the ~~target~~ as much as possible.

These suggestions should be confirmed by direct testing. This could be done while exploring another variable of great potential importance. A recent study has shown that fourfold increases in search time can occur, when the position of a target relative to nontarget clutter items is varied. Combining a direct test of our suggestions with an investigation of target placement seems to be the most efficient next step in developing the art of concealment.

SUMMARY

In this study of visual factors in target disruption, the objective was to determine the relationship between variations in the properties of disruptors, and to determine the effectiveness of those disruptors in concealing military targets from visual detection when they are placed in various classes of natural background. A disruptor is an umbrella-like object attached to a target in such a way as to obscure part of it.

Four background scenes were selected. They were low, oblique, aerial views of Virginia, Minnesota in the Fall, Minnesota in the Winter, and Nebraska. One of four military targets, a helicopter, tank, howitzer or truck, was placed in turn in each scene. A series of disruptive camouflage treatments was tested using the target-background imagery. Both the targets and disruptors were photographically embedded in the original scene.

Two experiments were carried out. In the first, 155 camouflaged conditions were compared with 16 uncamouflaged pictures. Variations were made in the color, size, number and location on the target of disruptors. At least 10 observers searched each of the 171 tested scenes. Search time and detection performance were recorded. In the second experiment, the 16 uncamouflaged target pictures were used with 16 of the more successful disruptor combinations. While each observer searched for the targets his/her eye movements were monitored with an oculometer. By comparing the position of the corneal reflection of an infrared source with the position of the center of the pupil, the oculometer gives the direction of the observer's line of sight. Eye movement patterns and detection performance were recorded. In both experiments, a vision test was used to ensure that

all observers had a near-visual acuity score of at least 20/20 and normal color vision. All observers also took part in a hidden figures test. There were 258 observers in the main experiment, and 24 in the oculometer study.

The result of comparing the 155 camouflaged treatments with the 16 uncamouflaged conditions was that the search time was significantly increased in 46 cases. The most successful camouflage occurred for all four targets in the Minnesota Fall scene, and for the howitzer in all four scenes. The increase in difficulty for these successful treatments produced search times that were two to four times as large as those obtained with the equivalent uncamouflaged targets.

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Where the ground is relatively dark, the basic color of the disruptor should be as dark as the ground. The effectiveness of the disruptor will be increased by adding to it colors that are even darker. For scenes in which the ground is relatively light in color, the disruptors may be basically colored like the foliage or they may include lighter colors that match the ground.

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To reduce the probability of a target being detected or of increasing the time required to detect it, the following suggestions are made. First, the target should be placed in an area with relatively dark ground and foliage, where the ground and foliage are heterogeneous rather than homogeneous. Next, the color used as the basis for the disruptive material should be as dark as the ground. The disruptors should also have other colors which are even darker. It will be most effective to use several small disruptors, placed to break up the outline of the target as much as possible.

These suggestions should be confirmed by direct testing. This could be done while exploring another variable of great potential importance. A recent study has shown that fourfold increases in search time can occur, when the position of a target relative to nontarget clutter items is varied. Combining a direct test of our suggestions with an investigation of target placement seems to be the most efficient next step in developing the art of concealment.

PREFACE

This final technical report is submitted to the U.S. Army Mobility Equipment and Research Development Center under contract number DAAK02-75-C-0055.

We wish to thank Albert Perri, Ronald Johnson and Bruce Bucklin of the Mobility and Equipment Research and Development Center, Fort Belvoir, Virginia for their advice and encouragement. We also wish to thank Phil Muller, Fred Rhode, Al Baldwin and John Fitzgerald of the Honeywell Ordnance Proving Ground for their help in obtaining the target imagery; Ray Roberts, Donald McDonald and Jerry Knapp of the Honeywell Photo Lab, without whom we could not have produced such high quality color imagery using embedding techniques; Jan Morgan, for assisting in the embedding process; Roxanne LeFebvre, for her help in running the main experiment and analyzing the data; and Len Lorence, for assisting in the running and analysis of the oculometer study.

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SECTION 1
INTRODUCTION

The overall objective of this effort was to systematically determine the relationship between variations in the properties of disruptors and the effectiveness of those disruptors in concealing military targets from visual detection when in various classes of natural background.

Visual search is necessary when, for some reason, a target object cannot be seen immediately. There are several reasons why it may be necessary. One of the most important is that the target may not emerge perceptually from its immediate background because the patterning of the target and background combine in some way; it is camouflaged.

There has been a considerable amount of research work in the general area of visual search, but very little of it has been directly concerned with background combine in some way to embed or camouflage it.

Search tasks employing embedded targets have been used in a few investigations. Most of these studies concentrated on secondary variables and have not dealt directly with the variables that define these search tasks. For example, Parkes (1967) found that skilled observers were able to search quicker than unskilled observers, and Williams (1966) showed that physically reducing the size of the search area while keeping the information content the same had no effect on performance. If these studies, and others like them that concentrate on secondary variables, had been performed with a search task that depended on some other search determinant (such as the

presence of competing nontargets), they would have showed essentially the same results. Only very recently, in work at the Naval Weapons Center at China Lake that was run concurrently with the present study, have some of the primary variables of camouflaged or embedded target search tasks been addressed (Whitehurst, 1975 a & b, Grossman, 1975 a & b).

Cott (1940) dealt with animal camouflage in a systematic way from a zoological viewpoint. He began the work of elucidating the variables involved when a predator hunts for a camouflaged prey. He isolated four principles of camouflage:

- <u>Color Resemblance</u> i.e., the similarity in the color of a target and of the background against which it is placed.
- <u>Obliterative Shading</u> i.e., counter lightening and darkening which aims to diminish the appearance of roundness or relief due to light and shade.
- <u>Disruptive Coloration</u> i.e., a superimposed pattern of contrasted colors and tones serving to blur the outline and break up the surface appearance of the target.
- <u>Shadow Elimination</u> i.e., the reduction in or removal of shadows cast by the target object.

One recent study has directly investigated camouflage visual search situations (Bloomfield, Marmurek and Traub, 1974). It dealt with situations in which the color resemblance of the target to the background was varied. Depth cues were eliminated. As the target and the background in which it was presented became more similar, search time increased. Search time was found to be inversely proportional to peripheral acuity and to the rated discriminability of the target from the background.

In the current study, disruptors were used in attempts to hide targets. A disruptor is an umbrella-like object that is attached to a target so that it obscures part of it. The material disruptors are covered with is chosen to resemble foliage. The color of the disruptors were varied in such a way that one or other or Cott's principles of color resemblance and disruptive coloration were used. The disruptors either resembled the immediate background against which the target was placed or they resembled the bushes and trees in the scene. In addition, the size, number, and location of disruptors were varied. The study was designed to show which values of the various properties of the disruptors were most effective in concealing four different targets in four different natural backgrounds.

Four representative background scenes were selected. One area in each was designated as a target area. Four 16 x 16-inch prints were made of each scene. Then one of four targets (helicopter, tank, howitzer and truck) was photographically added. The disruptors were also embedded photographically.

In the first experiment, 155 combinations of scene, target, disruptor color, size, number, and location were compared with 16 uncamouflaged pictures. At least 10 observers searched each of the 171 tested scenes. Search time and detection performance were recorded.

In a second experiment, the same 16 uncamouflaged target pictures were used along with 16 of the most successful disruptor combinations. While each of 24 observers searched the scenes, his/her eye movements were monitored with an oculometer. This device computes eye position from

a comparison of the position of the virtual image of an infrared source with the position of the center of the pupil. Here, eye movement patterns as well as search times and detection performance were recorded. Data from these two experiments provided the basis for recommendations as to the most effective combinations of disruptor variables.

SECTION 2
IMAGERY

BASIC IMAGERY

Four terrain pictures were selected. They were aerial color photographs taken from an oblique angle. The photographs were taken in Virginia, in Minnesota during the Fall and Winter, and in Nebraska. One of four military targets was added to each of these by an embedding process. The four targets were a helicopter, tank, howitzer, and truck. All but the helicopter had been pattern-painted using the most recently approved U.S. Army camouflage pattern painting colors and designs.

The targets were photographed from a low-flying helicopter and positioned on level ground. The helicopter approached each target at several different angles. On each approach a series of photographs were taken, each from a different aspect angle.

The four terrain background pictures were enlarged to 16 x 16-inch prints. Selected target images were processed so that they would be appropriate in size for the backgrounds. When adequate matches were achieved between targets and backgrounds, they were cut out, skinned, and added to the backgrounds. Photographic retouching colors were used to darken the backgrounds in providing suitable shadows for the targets.

DISRUPTORS

One basic disruptor shape was selected and several variants on this shape were prepared. This takes account of the fact that disruptors are not

mounted identically at all points on the vehicles. Their angle to the vertical can vary. When seen from an oblique angle from the air, variations in the basic shape result.

Four different disruptor colors were chosen. One color was chosen specifically for each of the four basic terrain backgrounds. Solid slabs of color were avoided. Instead, the disruptors had a mixed range of colors. The range was selected so that it resembled the range of colors used in the appropriate background. In two scenes, Minnesota Fall and Nebraska, the selected colors resulted in the disruptor having coloring similar to the ground and the foliage. In the other two scenes, Virginia and Minnesota Winter, the ground and foliage were very different from each other. As a result, only one match was attempted, to the foliage.

The disruptors were painted on photographic paper. Photographic retouching colors were used and then the disruptors were photographed and reduced. Three disruptor sizes were chosen, covering an area approximately 16, 25, or 38 percent of the area of the tank.

The number of disruptors was varied. With the 16 percent size, there were one, two or four disruptors; with the 25 and 38 percent size, there were one or two disruptors.

The location of the disruptors was varied for some combinations of size and number. When one disruptor was used, whether of the 16, 25 or 38 percent size, there were three possible positions. When two of the 16 or 25 percent size were used, the same three locations as for the one disruptor case were used. In these cases, each of the three locations was omitted in turn. When two 38 percent disruptors were used, two locations only

were used. Similarly, with four 16 percent disruptors, only four locations were used. In all cases the locations were selected because they obscured what were judged to be the most distinctive features of the targets from the viewing angles used. The four locations selected in order of preference were: the windshield, prop shaft, tail, and landing struts (for the helicopter); the turret and nearest corner, turret and near side, turret and far side, and gun barrel and furthest corner (for the tank); and windshield, lower rear corner (including back wheel), hood, and top rear corner (for the tank). The three locations used for the howitzer were: center (over wheel), rear part of carriage (not including the wheel), and gun barrel.

The disruptors were placed directly on the 16 x 16-inch photographs containing the embedded targets. The results were photographed and 35 mm color slides were made. These provided the basic stimulus materials for the study.

Examples of the imagery are shown in Figures 1 through 8. Figure 1 shows an uncamouflaged helicopter in the Virginia scene. Figure 2 shows the same target with disruptors. Figure 3 shows a tank in the Minnesota Fall scene. Figure 4 shows the tank camouflaged. Figure 5 shows the truck in the Minnesota Winter scene. Figure 6 shows same truck with disruptors. Figure 7 shows the howitzer in the Nebraska scene. Figure 8 shows the camouflaged howitzer.

Figure 1. Uncamouflaged Helicopter in Virginia Scene

Figure 2. Camouflaged Helicopter in Virginia Scene

Figure 3. Uncamouflaged Tank in Minnesota Fall Scene

Figure 4. Camouflaged Tank in Minnesota Fall Scene

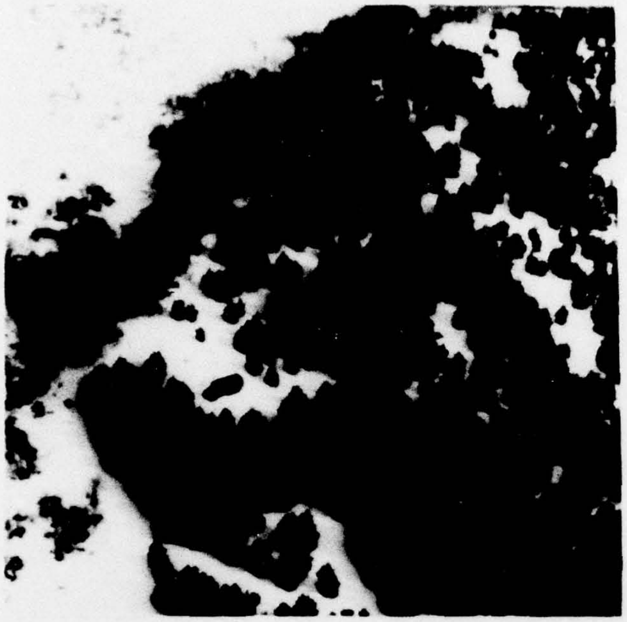

Figure 5. Uncamouflaged Truck in Minnesota Winter Scene

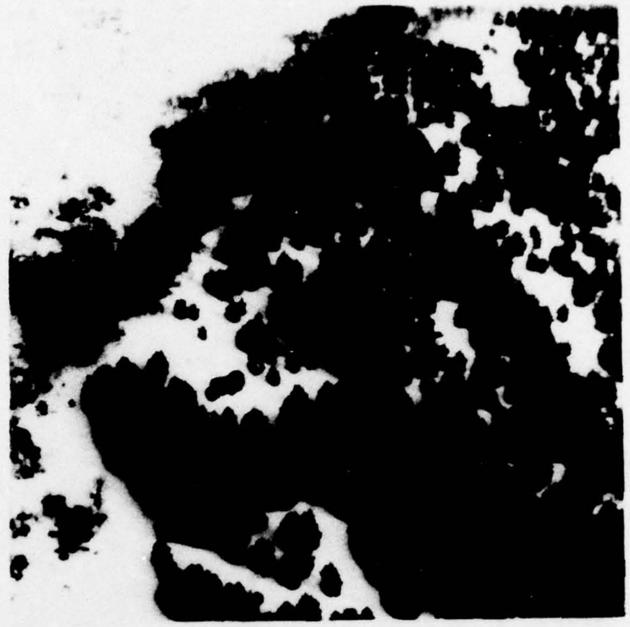

Figure 6. Camouflaged Truck in Minnesota Winter Scene

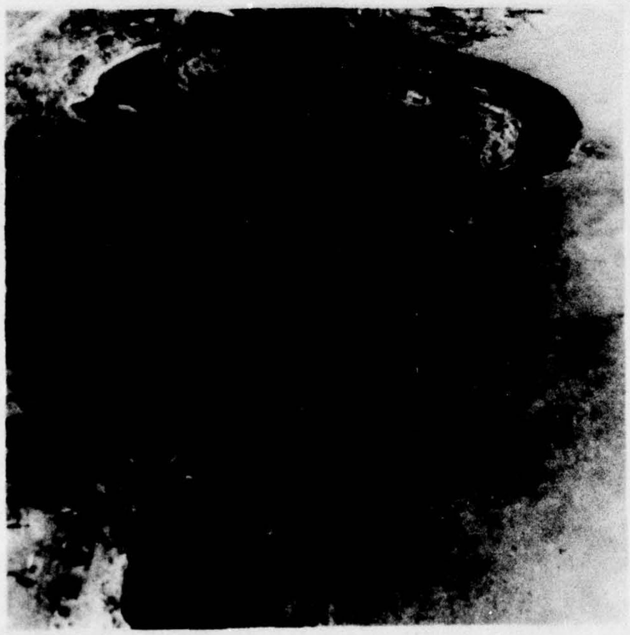

Figure 7. Uncamouflaged Howitzer in Nebraska Scene

Figure 8. Camouflaged Howitzer in Nebraska Scene

SECTION 3
METHOD

DESIGN

The main experiment involved four terrain backgrounds, four targets, four disruptor colors and 17 disruptor size-number-location combinations. Including the 16 uncamouflaged target-background combinations, a full factorial design would have had 1,104 cells, a prohibitively large number. A partial design was devised. Testing began using what appeared to be the most successful camouflage treatments. These were compared with the uncamouflaged scenes. Further amendments were made after this initial testing. The final number of cells tested was 171.

Table 1 lists the full matrix of 1,088 camouflage conditions and shows the 155 that were selected for comparison with the 16 uncamouflaged conditions. The targets were coded as follows:

1 - Helicopter	2 - Tank
3 - Howitzer	4 - Truck

The scenes and the disruptor colors which were derived from them are coded as follows:

Code	Scene	Disruptor Color
A	Virginia	Dark Green
B	Minnesota, Fall	Light Green
C	Minnesota, Winter	Blue Green
D	Nebraska	Grey Brown

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B	Minnesota, Fall	Light Green
C	Minnesota, Winter	Blue Green
D	Nebraska	Grey Brown

SCENE:
A (Virginia)

Table 1. Full Matrix of Camouflage Conditions - Cells with an O Were Tested

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	0	-	-	0	0	-	0	-	-	-	-	-	-	-	0	0
		2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	0	-	0	-	-	-	0	0	-	-	-	-	0	-	-	0
		2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	0	0	-	-	-	0	-	-	-	-	-	-	-	0	-	0
25%	1	1	0	-	0	-	-	-	0	0	-	-	-	-	0	-	-	0
		2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	0	0	-	-	-	0	0	-	-	-	-	-	-	0	-	0
		2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	0	0	-	-	-	0	0	-	-	-	-	-	-	0	-	0
		2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

SCENE:
B (Minnesota Fall)

Table 1. Cells with an O Were Tested (Continued)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	0	0	-	0	0	-	-	0	-	-	-	-	0	-	-	-
25%	1	1	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	0	-	0	-	-	-	-					-	-	-	-
	2	1	0	0	0	0	0	-	-	-	-	-	-	-	0	0	-	-
		2	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	0	0	0	0	0	-	-	-	-	-	-	-	0	-	-	-
		2	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-

SCENE:
C(Minnesota, Winter)

Table 1. Cells with an O Were Tested (Continued)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	-	-	-	0	-	-	-	-	-	0	-	-	0	-	-	-
25%	1	1	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-

SCENE:
D (Nebraska)

Table 1. Cells with an O Were Tested (Concluded)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	-	0	0	-	0	0	-	-	-	-	-	-	0	-	0	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	2	1	0	0	-	-	0	-	0	-	-	-	-	-	-	0	0	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	4	1	-	0	-	0	0	-	-	0	-	-	-	-	-	-	-	0
25%	1	1	0	0	-	-	0	-	0	-	-	-	-	-	-	0	0	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	2	1	-	0	-	0	0	-	-	0	-	-	-	-	-	-	0	0
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
38%	1	1	-	0	-	0	0	-	-	0	-	-	-	-	-	-	0	0
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	2	1	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-

At least one disruptor color was omitted entirely from each of the four scenes. The color developed for the snow scene was ineffective when used in the other three backgrounds. The disruptor devised for the Minnesota Fall scene did not seem appropriate for the snow scene. In addition, initial testing suggested that the colors devised for the Minnesota Fall and Nebraska scenes had little effect in the Minnesota Fall scene, and the colors devised for the Minnesota Winter and Nebraska scenes had little effect in the Minnesota Winter scene. Because of this, changes were made in design. In spite of the large-scale reduction in the number of cells, it was still possible to obtain some information on all of the remaining variables. Comparisons could be made that show the most effective color, location, size, and number of disruptors. However, possible interaction effects between these variables could not be investigated. In order to cover all of the empty cells in Table 1, a much larger study would be necessary. The very selective pruning technique used here maximized the information obtained while greatly reducing the cost of obtaining it.

APPARATUS

Figure 9 shows the experimental apparatus. It contains the following:

- Ground glass rear projection screen
- Projector
- Electrically operated shutter
- Switch
- Digital timer
- Power supply

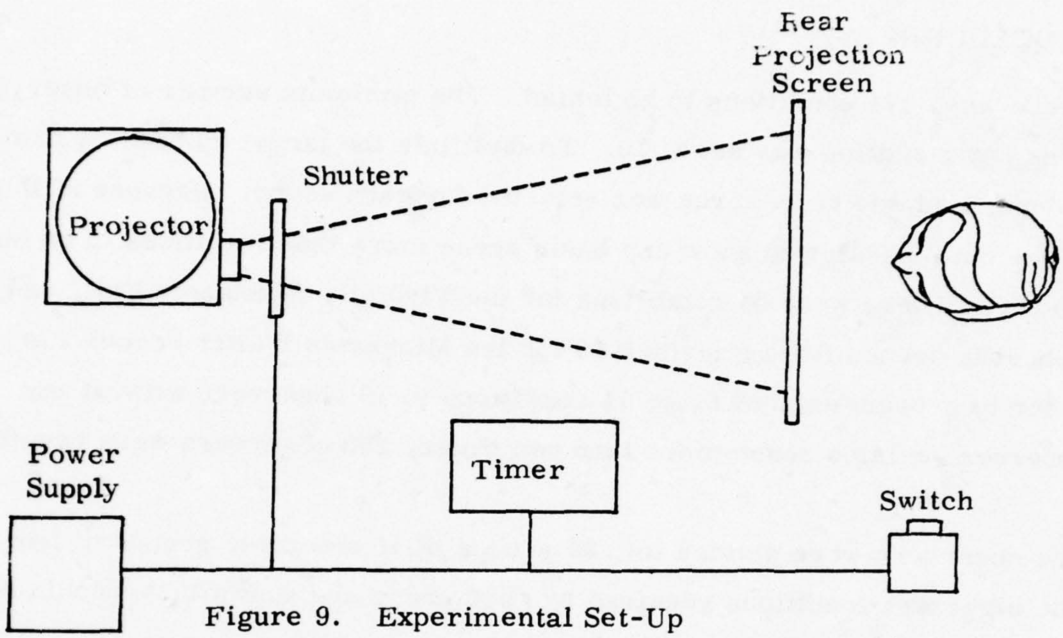

Figure 9. Experimental Set-Up

The observer sat so that his/her eyes were 13 inches from the rear projection screen. Imagery was projected onto this screen by means of the projector. A shutter was placed between the screen and the projector. At the beginning of each test trial, the switch was depressed to open the shutter and start the timer. When the observer located the target, the switch was released to close the shutter and stop the timer. The length of time the test imagery was visible was then recorded.

The distance between the projector and the back projection screen was set so that the test imagery was 8 x 8-inches square. With a viewing distance of 13 inches, this resulted in an image that was $34^{\circ}12'$ square at the observer's eye.

PROCEDURE

There were 171 conditions to be tested. The minimum number of observations per condition was set at 10. To facilitate the target embedding procedure, a single target area was selected for each scene. Because of this, it was not advisable to show any basic scene more than two times to an observer. There were 51 conditions for the Virginia, Minnesota Fall, and Nebraska scenes (with a further 18 for the Minnesota Winter scene). In order to present each of those 51 conditions to 10 observers without any observer seeing a scene more than two times, 255 observers were required.

The observers were divided into 24 groups of 10 and three groups of five. The eight test conditions received by each group are shown in Appendix A.

Only 18 Minnesota Winter scenes were included in the final design. All of them had been viewed by 10 observers after nine groups had been tested. In order not to change the basic experiment, these 18 scenes were repeated in later groups. Consequently, these scenes were shown to 20, 30 or 40 different observers. Larger numbers occur for the howitzer and helicopter targets since these were tested less often that the tank and the truck in the other backgrounds. The repetition of these scenes enabled comparison of different observer groups.

The order of presentation was arranged so that each observer viewed one example of each background scene in the first four trials, with a second example of each reversed left to right in the second set of four trials. The order was rotated from one observer to the next in the same group so that any possible practice effects would be spread across the conditions. At the start of the experiment, the observer was shown the four possible targets against a white

background and asked to familiarize himself/herself with them. Then a series of four test slides were presented, one of each of the four backgrounds. When a slide was placed in the projector, the observer depressed the switch and held it down until he/she thought the target had been located. A maximum of 90 seconds was allowed on each trial. The observer then released the switch and pointed at the then-blank screen to indicate the area in which he/she thought the target had been positioned. The experimenter recorded the length of time the shutter had been open, whether or not the observer had correctly detected the target and, if there had been a false detection, the position in which the observer thought the target had been. Next, the experimenter placed a second test slide in the projector and repeated the procedure.

After a set of four slides, the observer was given a brief vision test and took part in a hidden figures test. Finally, four more test slides were presented. This time they were reversed left to right. The observer's near-visual acuity was measured and his/her ability to discriminate colors was investigated using six Ishahari Pseudo-Isochromatic Plates. This procedure was used as a screening device, with acuity of at least 20/20 and a color discrimination of at least five out of eight required.

There are several hidden figures tests. The shortened form of Witkin's version (Jackson, 1956) was used. Using the main experimental apparatus, the observer was shown a series of 13 slides. In all of them a simple black and white figure was presented on the left and a more complex,usually colored figure was presented on the right. The first slide was a practice slide. For the remaining 12 slides, the experimenter operated the switch

to begin a trial. The observer had to search the more complex figure and try to locate in it the simple figure. It was then necessary for the observer to trace the outline of the simple figure. As soon as it had been correctly traced, the experimenter released the timing switch, and recorded the length of time the shutter had been open. The same procedure was repeated for all 12 hidden figures test slides. The observer was allowed up to three minutes to search each complex figure.

The instructions to the observers for the search task, the vision test, and the hidden figures test are presented in Appendix B.

OCULOMETER EXPERIMENT

The results of the main experiment indicated those camouflage treatments that had been most successful. One of the more successful treatments for each target and background combination was selected for inclusion in a further experiment. They were tested with the 16 uncamouflaged target pictures.

The basic procedure was the same as in the main experiment. The main difference was that while the observer was searching the test slide, his/her eye movements were recorded, using a Honeywell viewing hood oculometer.

The oculometer is a device that measures eye position. The observer views the displayed imagery via a viewing hood which fixes the viewing distance at 20.5 inches. While the observer looks at the imagery, infrared radiation is reflected off the cornea of the left eye onto a vidicon. The position of the virtual image of the infrared source is compared with the

position of the center of the pupil. Changes in the angular position of the observer's eye cause changes in the relative positions of these two features and a corresponding change in the output of the oculometer. Two voltages which correspond to the horizontal and vertical components of the observer's eye position are sampled 50 times per second and recorded on digital tape by a DDP-24 computer and analog-to-digital converter. This data is stored and analyzed in relation to the imagery presented to the observer.

The experiment began with the vision test. Then a calibration procedure was used so that it would be possible to relate the oculometer voltages to the displayed imagery during analysis. The first set of test slides were presented with the eye movements of the observer monitored. The hidden figures were presented as in the main experiment. Finally, the last four test slides were presented while eye movements were again recorded.

The observer's head was 20.5 inches from the screen. With test imagery 10 x 10-inches square, this resulted in imagery that was $27^{\circ}25'$ square at the observer's eye.

Two observers failed the vision test and a further five could not be calibrated on the oculometer. No further data was taken from these observers.

There were 24 observers tested using the oculometer. Each searched eight pictures, so each of the 32 scenes was searched by six observers.

OBSERVERS

The study was run in three locations: at Honeywell Systems and Research Center, Hamline University, and Macalester College. In all, 302 observers were tested: 278 in the main study and 24 in the oculometer experiment. Data from 20 observers were rejected from the main experiment because the observers had acuity that was worse than 20/20 or because they failed the color discrimination test.

SECTION 4
RESULTS

VISION TEST

The vision test was used as a selection device. A Snellen fraction of at least 20/20 was required for the near-visual acuity test. On the color discrimination test correct identification of five out of eight digits was required. For the main experiment, 278 observers took this test. Twenty were rejected because they failed the acuity or color discrimination test.

SEARCH DATA

It was hypothesized that longer search times would be obtained in trials with camouflaged targets than trials in which they were uncamouflaged. The Kolmorogrov-Smirnov two-sample; one-tailed test was used to test this hypothesis.

Siegel (1956) argues that this test is more powerful in all cases than the chi-squared or median tests, and for small samples, like those used here, it is more efficient than the Mann-Whitney test.

The Minnesota Winter conditions were used with two, three or four groups of observers. To handle the unequal sample sizes, the following equation was used:

$$\chi^2 = 4D^2 \frac{n_1 n_2}{n_1 + n_2} \qquad (1)$$

where D is the maximum difference between two cumulative distributions in the Kolmorogrov-Smirnov test, and n_1 and n_2 are the sample sizes of the two distributions. Goodman (1954) showed this equation had a sampling

distribution approximated by the chi-squared distribution with two degrees of freedom.

The Kolmorogrov-Smirnov test has a power-efficiency that is 96 percent of that of the t test (Dixon, 1954). With some of our comparisons where significance was almost achieved - a t test, after a logarithmic transformation - was performed. In four cases this procedure produced significant differences. The t test was not used as a primary tool because the Kolmorogrov-Smirnov test is almost as effective, and because even after an appropriate transformation, some search data does not meet the requirements of equal variance and normalcy required for parametric tests.

Of the 155 camouflage treatments, 46 significantly increased search time when compared with the data from the appropriate uncamouflaged target.

Table 2 shows the full test matrix. It shows again which conditions were tested and the 46 that significantly increased search time. Table 2 lists results of comparing 155 camouflaged conditions with appropriate uncamouflaged conditions.

SCENE:
A (Virginia)

Table 2. Results of Comparing 155 Camouflaged Conditions with Appropriate Uncamouflaged Conditions

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	NS	-	-	NS	NS	-	.01	-	-	-	-	-	-	-	.01	NS
		2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	NS	-	.001	-	-	-	01	NS	-	-	-	-	NS	-	-	NS
		2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	.05*	NS	-	-	-	NS	-	-	-	-	-	-	-	NS	-	.05*
25%	1	1	NS	-	.01	-	-	-	.05	NS	-	-	-	-	NS	-	-	NS
		2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	NS	NS	-	-	-	NS	.001	-	-	-	-	-	-	NS	-	.01
		2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	NS	NS	-	-	-	NS	.05	-	-	-	-	-	-	NS	-	NS
		2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS

Key: NS = treatments with no significant effect * = t test used

Table 2. Results of Comparing 155 Camouflaged Conditions with Appropriate Uncamouflaged Conditions (Continued)

SCENE:
B (Minnesota, Fall)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	-	NS	.05	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	NS	.10	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	.01	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	.05	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	.01	.01	-	NS	.10	-	-	NS	-	-	-	-	.05*	-	-	-
25%	1	1	-	NS	.01	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	NS	NS	.01	NS	NS	-	-	-	-	-	-	-	.01	NS	-	-
		2	-	.05	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	NS	NS	NS	NS	NS	-	-	-	-	-	-	-	.05	-	-	-
		2	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	NS	-	.01	-	-	-	-	-	-	-	-	-	-	-	-

Key: NS = treatments with no significant effect   * = t test used

Table 2. Results of Comparing 155 Camouflaged Conditions with Appropriate Uncamouflaged Conditions (Continued)

SCENE:
C (Minnesota, Winter)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	NS	-	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	NS	-	.02	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	1	-	-	-	.05	-	-	-	-	-	.10	-	-	NS	-	-	-
25%	1	1	-	NS	-	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	-	.001	NS	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38%	1	1	-	-	NS	.10	-	-	-	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1	-	-	-	.05	-	-	-	-	-	-	-	-	-	-	-	-

Key: NS = treatments with no significant effect   * = t test used

Table 2. Results of Comparing 155 Camouflaged Conditions with Appropriate Uncamouflaged Conditions (Concluded)

SCENE:
D (Nebraska)

			DISRUPTOR COLOR															
			A				B				C				D			
			Target				Target				Target				Target			
Size	Number	Location	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
16%	1	1	-	NS	NS	-	NS	NS	-	-	-	-	-	-	NS	-	.01	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
	2	1	NS	NS	-	-	NS	-	NS	-	-	-	-	-	-	NS	.10	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.05	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.05	-
	4	1	-	.10	-	NS	.10*	-	-	NS	-	-	-	-	-	-	-	NS
25%	1	1	NS	NS	-	-	NS	-	NS	-	-	-	-	-	-	NS	NS	-
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
	2	1	-	NS	-	NS	NS	-	-	NS	-	-	-	-	-	-	.05	NS
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
38%	1	1	-	NS	-	NS	NS	-	-	NS	-	-	-	-	-	-	.01	NS
		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.05	-
		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.01	-
	2	1	-	NS	-	-	NS	-	-	-	-	-	-	-	-	-	-	-

Key: NS = treatments with no significant effect   * = t test used

As a measure of average search time, the geometric mean $(\pi_{i=1}^{n} X_i)^{(1/n)}$ was used. This was used recently by Monk (Monk, 1974; Monk and Brown, 1975). It appears to be the best available measure of central tendency; it is the exponential of the mean of the logarithmically transformed data.

Table 3 shows the geometric mean search time for the 171 conditions used in this experiment. The table lists the number of observers who viewed each of the conditions. Then it lists the number of false alarms (occasions on which a false detection occurred) and the number of failures to detect a target in a 90-second period. Both false alarms and failures to detect were included in the computation of geometric mean. The measures used for them were the time taken to make an incorrect detection (false alarms) and 90 seconds (failures). Both of these measures are underestimates; the true geometric mean time is at least as large as the value shown here. The table also lists the number of correctly identified and detected targets as well as the probabilities associated with those conditions that produced search times significantly different from the uncamouflaged targets. The statistical test used to calculate the probabilities is also shown.

Each of the 155 camouflage conditions was compared with the appropriate uncamouflaged condition to see whether there was an increase in search time. In 46 cases there was a significant increase. It can be seen from Table 3 that in a number of the remaining 109 cases, the geometric mean was less than that of the appropriate uncamouflaged case. Since we only used one-tail test to reveal significant increases, our statistical procedures give us information on reductions in time. Inspection of Table 3 shows that for the most part, the reductions were small. Only in nine of the 109

Table 3. Average Search Time for 171 Conditions Used in the Main Experiment

Scene A

Target 1:Helicopter				Mean	N	F	UD	I	P	Test
Uncamouflaged				1.95	10	-	-	10		
Color	Size	No.	Loc.							
A	16	1	1	1.94	10	-	-	10	-	-
A	16	1	2	1.42	10	-	-	10	-	-
A	16	1	3	1.43	10	-	-	10	-	-
A	16	2	1	2.01	10	-	-	10	-	-
A	16	2	2	1.57	10	-	-	10	-	-
A	16	2	3	1.44	10	-	-	9	-	-
A	16	4	1	2.96	10	1	-	4	<.05	t
A	25	1	1	1.34	10	-	-	10	-	-
A	25	1	2	2.07	10	-	-	9	-	-
A	25	1	3	1.09	10	1	-	9	-	-
A	25	2	1	1.96	10	-	-	10	-	-
A	25	2	2	1.70	10	-	-	10	-	-
A	25	2	3	1.73	10	-	-	9	-	-
A	38	1	1	1.30	10	-	-	9	-	-
A	38	1	2	1.28	10	-	-	8	-	-
A	38	1	3	1.39	10	-	-	9	-	-
A	38	2	1	2.18	10	-	-	5	-	-
B	16	1	1	1.34	10	-	-	10	-	-
D	16	2	1	1.69	10	-	-	10	-	-
D	25	1	1	1.12	10	-	-	10	-	-

Target 2:Tank				Mean	N	F	UD	I	P	Test
Uncamouflaged				1.38	10	-	-	10		
Color	Size	No.	Loc.							
A	16	4	1	1.91	10	-	-	10	-	-
A	25	2	1	1.33	10	-	-	10	-	-
A	38	1	1	1.20	10	-	-	10	-	-
B	16	4	1	2.21	10	1	-	9	-	-
B	25	2	1	1.82	10	-	-	8	-	-
B	38	1	1	1.18	10	-	-	10	-	-
D	16	4	1	1.72	10	-	-	10	-	-
D	25	2	1	1.46	10	-	-	10	-	-
D	38	1	1	1.36	10	-	-	10	-	-

Target 3:Howitzer				Mean	N	F	UD	I	P	Test
Uncamouflaged				3.05	10	-	-	10		
Color	Size	No.	Loc.							
A	16	2	1	14.00	10	6	3	1	<.001	K-S
A	25	1	1	10.87	10	3	-	7	<.01	K-S
B	16	1	1	5.64	10	3	-	6	<.01	K-S
B	16	2	1	28.27	10	4	2	3	<.01	K-S
B	25	1	1	4.70	10	2	-	8	<.05	K-S
B	25	2	1	20.89	10	4	2	2	<.001	K-S
B	38	1	1	8.80	10	4	1	3	<.05	K-S
D	16	1	1	5.51	13	5	-	8	<.01	K-S

Target 4:Truck				Mean	N	F	UD	I	P	Test
Uncamouflaged				1.42	10	-	-	10		
Color	Size	No.	Loc.							
A	16	1	1	1.39	10	-	-	10	-	-
B	16	2	1	1.38	10	-	-	10	-	-
B	25	1	1	1.15	13	-	-	13	-	-
D	16	1	1	1.39	10	-	-	9	-	-
D	16	2	1	1.54	10	-	-	9	-	-
D	16	4	1	1.75	10	-	-	8	<.05	t
D	25	1	1	1.22	10	-	-	9	-	-
D	25	2	1	2.16	10	-	-	10	<.01	K-S
D	38	1	1	1.44	10	-	-	9	-	-
D	38	2	1	1.74	10	-	-	6	-	-

Key

A = dark green color

B = light green color

C = blue green color

D = grey brown color

Mean = Geometric Mean Search Time

N = number of observers on which mean is based

F = number of false alarms

UD = number of failures to detect target in 90 seconds

I = number of correctly identified and detected targets

P = probability

Test = statistical test used

- t = t test
- K-S = Kolomorogrov-Smirnov Test
- χ^2, K-S = χ^2 Test using Kolomorogrov-Smirnov D

Table 3. Average Search Time for 171 Conditions Used in the Main Experiment (continued)

Scene B

Target 1:Helicopter				Mean	N	F	UD	I	P	Test
Uncamouflaged				2.62	10	-	-	9		
Color	Size	No.	Loc.							
A	16	4	1	9.98	10	2	-	2	≤.01	K-S
A	25	2	1	2.64	10	-	-	8	-	-
A	38	1	1	3.04	10	-	-	6	-	-
B	16	4	1	8.72	10	3	-	2	≤.10	K-S
B	25	2	1	2.47	10	-	-	8	-	-
B	38	1	1	3.53	10	-	-	7	-	-
D	16	4	1	6.00	10	-	-	4	≤.05	t
D	25	2	1	7.86	10	1	-	7	≤.01	K-S
D	38	1	1	6.32	10	1	-	9	≤.05	K-S

Target 3:Howitzer				Mean	N	F	UD	I	P	Test
Uncamouflaged				4.62	10	1	-	8		
Color	Size	No.	Loc.							
A	16	1	1	10.96	10	2	-	7	≤.05	K-S
A	16	2	1	10.59	10	3	-	3	≤.10	K-S
A	25	1	1	8.08	10	5	-	4	≤.01	K-S
A	25	2	1	27.31	10	5	3	1	≤.01	K-S
A	38	1	1	7.42	10	1	-	3	-	-

Target 2:Tank				Mean	N	F	UD	I	P	Test
Uncamouflaged				2.02	10	-	-	10		
Color	Size	No.	Loc.							
A	16	1	1	1.71	10	-	-	10	-	-
A	16	1	2	1.84	10	1	-	6	-	-
A	16	2	1	1.43	10	-	-	9	-	-
A	16	2	2	5.32	10	1	-	4	≤.01	K-S
A	16	2	3	3.40	10	2	-	7	≤.05	K-S
A	16	4	1	6.77	10	-	-	5	≤.01	K-S
A	25	1	1	1.90	10	-	-	9	-	-
A	25	1	2	1.40	10	-	-	8	-	-
A	25	1	3	1.86	13	-	-	13	-	-
A	25	2	1	1.77	10	-	-	10	-	-
A	25	2	2	4.77	10	1	-	7	≤.05	K-S
A	25	2	3	1.98	10	1	-	6	-	-
A	38	1	1	2.06	10	-	-	8	-	-
A	38	1	2	2.31	10	-	-	8	-	-
A	38	1	3	2.00	10	-	-	10	-	-
A	38	2	1	2.05	10	1	-	7	-	-
D	25	2	1	2.33	10	-	-	10	-	-

Target 4:Truck				Mean	N	F	UD	I	P	Test
Uncamouflaged				3.68	10	-	-	10		
Color	Size	No.	Loc.							
A	16	1	1	3.72	10	-	-	8	-	-
A	16	2	1	2.44	10	-	-	8	-	-
A	16	2	2	4.40	10	1	-	3	-	-
A	16	2	3	3.33	10	-	-	6	-	-
A	16	4	1	3.09	10	-	-	5	-	-
A	25	1	1	3.95	10	-	-	10	-	-
A	25	1	2	4.05	10	-	-	9	-	-
A	25	1	3	3.15	13	-	-	10	-	-
A	25	2	1	6.28	10	1	-	7	-	-
A	25	2	2	3.02	10	-	-	5	-	-
A	25	2	3	2.10	10	-	-	2	-	-
A	38	1	1	3.09	10	1	-	6	-	-
A	38	1	2	3.29	10	1	-	6	-	-
A	38	1	3	4.32	10	3	-	5	-	-
A	38	2	1	10.74	10	4	1	1	≤.01	K-S
B	16	4	1	3.44	10	-	-	10	-	-

Key

A = dark green color

B = light green color

C = blue green color

D = grey brown color

Mean = Geometric Mean Search Time

N = number of observers on which mean is based

F = number of false alarms

UD = number of failures to detect target in 90 seconds

I = number of correctly identified and detected targets

P = probability

Test = statistical test used

- t = t test
- K-S = Kolomorogrov-Smirnov Test
- χ^2, K-S = χ^2 Test using Kolomorogrov-Smirnov D

Table 3. Average Search Time for 171 Conditions Used in the Main Experiment (continued)

Scene C

Color	Size	No.	Loc.	Mean	N	F	UD	I	P	Test
Target 1:Helicopter										
Uncamouflaged				1.08	30	-	-	30		
A	16	1	1	1.20	30	-	-	30	-	-
D	16	4	1	1.10	33	-	-	32	-	-
Target 2:Tank										
Uncamouflaged				1.08	30	-	-	29		
A	16	2	1	1.10	30	-	-	29	-	-
A	25	1	1	1.05	30	-	-	28	-	-
C	16	4	1	1.39	20	-	-	18	<.10	χ^2, K-S
Target 3:Howitzer										
Uncamouflaged				1.63	30	-	-	26		
A	25	2	1	3.40	40	2	-	19	<.001	χ^2, K-S
A	38	1	1	1.73	40	-	-	15	-	-
Target 4:Truck										
Uncamouflaged				1.01	33	-	-	32		
A	16	1	1	0.97	30	-	-	28	-	-
A	16	2	1	1.18	20	-	-	20	<.02	χ^2, K-S
A	16	4	1	1.39	30	-	-	21	.05	χ^2, K-S
A	25	1	1	1.04	20	-	-	20	-	-
A	25	2	1	1.11	20	-	-	19	-	-
A	38	1	1	1.19	20	-	-	13	<.10	χ^2, K-S
A	38	2	1	1.28	30	1	-	11	<.05	χ^2, K-S

<u>Key</u>

A = dark green color
B = light green color
C = blue green color
D = grey brown color
Mean = Geometric Mean Search Time
N = number of observers on which mean is based
F = number of false alarms
UD = number of failures to detect target in 90 seconds
I = number of correctly identified and detected targets
P = probability
Test = statistical test used
- t = t test
- K-S = Kolomorogrov-Smirnov Test
- χ^2, K-S = χ^2 Test using Kolomorogrov-Smirnov D

Table 3. Average Search Time for 171 Conditions Used in the Main Experiment (concluded)

Scene D

Target 1:Helicopter				Mean	N	F	UD	I	P	Test
Uncamouflaged				2.26	10	-	-	10		
Color	Size	No.	Loc.							
A	16	2	1	1.41	10	-	-	9	-	-
A	25	1	1	1.52	10	-	-	10	-	-
B	16	1	1	1.28	10	-	-	10	-	-
B	16	2	1	1.10	10	-	-	10	-	-
B	16	4	1	2.89	10	2	-	6	$\leq$ .10	t
B	25	1	1	1.35	10	-	-	10	-	-
B	25	2	1	1.00	13	-	-	12	-	-
B	38	1	1	1.52	10	-	-	10	-	-
B	38	2	1	1.41	10	-	-	10	-	-
D	16	1	1	1.21	10	-	-	10	-	-

Target 3:Howitzer				Mean	N	F	UD	I	P	Test
Uncamouflaged				2.03	10	1	-	9		
Color	Size	No.	Loc.							
A	16	1	1	2.71	10	-	-	3	-	-
B	16	2	1	2.28	10	-	-	8	-	-
B	25	1	1	2.10	10	-	-	5	-	-
D	16	1	1	4.47	10	-	1	8	.01	K-S
D	16	1	2	2.13	10	-	-	8	.10	K-S
D	16	1	3	2.65	10	-	-	6	.10	K-S
D	16	2	1	3.39	10	1	-	7	.10	K-S
D	16	2	2	2.26	10	1	-	5	.05	K-S
D	16	2	3	4.18	10	-	-	9	.05	K-S
D	25	1	1	2.10	10	-	-	4	-	-
D	25	1	2	2.85	10	-	-	9	.10	K-S
D	25	1	3	2.55	10	-	-	7	.10	K-S
D	25	2	1	4.38	10	-	-	4	.05	K-S
D	25	2	2	2.48	10	-	-	6	-	-
D	25	2	3	3.92	10	-	-	9	.10	K-S
D	38	1	1	6.35	10	1	-	2	.01	K-S
D	38	1	2	5.16	10	1	-	7	.05	K-S
D	38	1	3	4.02	10	1	-	7	.01	K-S

Target 2:Tank				Mean	N	F	UD	I	P	Test
Uncamouflaged				1.29	10	-	-	10		
Color	Size	No.	Loc.							
A	16	1	1	0.97	10	-	-	10	-	-
A	16	2	1	1.47	10	-	-	10	-	-
A	16	4	1	1.84	10	-	-	10	$\leq$ .10	K-S
A	25	1	1	1.03	13	-	-	13	-	-
A	25	2	1	1.19	10	-	-	10	-	-
A	38	1	1	1.18	10	-	-	10	-	-
A	38	2	1	1.67	10	-	-	9	-	-
B	16	1	1	1.18	10	-	-	10	-	-
D	16	2	1	1.04	10	-	-	10	-	-
D	25	1	1	1.40	10	-	-	9	-	-

Target 4:Truck				Mean	N	F	UD	I	P	Test
Uncamouflaged				2.93	10	1	-	9		
Color	Size	No.	Loc.							
A	16	4	1	3.42	10	-	-	2	-	-
A	25	2	1	1.67	10	-	-	5	-	-
A	38	1	1	2.20	10	-	-	5	-	-
B	16	4	1	2.19	10	-	-	4	-	-
B	25	2	1	2.19	10	-	-	1	-	-
B	38	1	1	3.18	10	-	-	4	-	-
D	16	4	1	3.58	10	1	-	8	-	-
D	25	2	1	2.78	10	1	-	1	-	-
D	38	1	1	2.52	10	-	-	10	-	-

Key

A = dark green color
B = light green color
C = blue green color
D = grey brown color
Mean = Geometric Mean Search Time

N = number of observers on which mean is based
F = number of false alarms
UD = number of failures to detect target in 90 seconds
I = number of correctly identified and detected targets

P = probability
Test = statistical test used
t = t test
K-S = Kolomorogrov-Smirnov Test
χ^2, K-S = χ^2 Test using Kolomorogrov-Smirnov D

cases was there a reduction of 40 percent or more. Two of the nine were for the helicopter in Scene A (disruptor conditions A-25-1-3 and B-25-1-1); one was for the truck in Scene B (A-25-2-3); and six were in Scene D, five with the helicopter (B-16-1-1, B-16-2-1, B-25-1-1, B-25-2-1, and D-16-1-1) and one with the truck (A-25-1-1). These reductions are large enough to challenge the assumption that if a particular camouflage treatment does not work, it will not make the target easier to see. At least for these nine, the indications are that the treatments probably did make it easier to detect the targets.

Scene and Target Difficulty

Comparisons between scenes and between targets were made using data from the uncamouflaged target pictures. Table 4 shows the geometric mean times for these targets in the four scenes.

Table 4. Geometric Mean Search Time (Seconds) for Uncamouflaged Targets

	Scene			
Target	A	B	C	D
1. Helicopter	1.95	2.62	1.08	2.26
2. Tank	1.38	2.02	1.08	1.29
3. Howitzer	3.05	4.62	1.63	2.03
4. Truck	1.42	3.68	1.01	2.93

The distributions of search times were compared first between scenes for each target, then between targets for each scene. Tables 5 and 6 show the results of this comparison.

Table 5. Scene Difficulty Compared for Uncamouflaged Conditions

1	2	3	4	5
	B	D	A	C
B	-	2(.05), 3(.10)	1(.05), 2(.10) 4(.01)	1(.001), 2(.01) 3(.01), 4(.001)
D		-	4(.01)	1(.001), 4(.001)
A			-	1(.05), 3(.05) 4(.01)
C				-

Target 1 = Helicopter, 2 = Tank, 3 = Howitzer, 4 = Truck.

Table 5 shows targets for which scenes in Column 1 take longer to search than scenes in Columns 2 through 5 (significance level shown in parenthesis).

As shown in Table 5, the order of difficulty for the scenes (from hardest to easiest to search) was Minnesota Fall, Nebraska, Virginia, and Minnesota Winter. Of 24 comparisons summarized in Table 5, 15 were significant (four at the .001 level, six at the .01 level, four at the .05 level, and two at the .10 level).

Table 6. Target Difficulty Compared for Uncamouflaged Conditions

1	2	3	4	5
	Howitzer	Helicopter	Truck	Tank
Howitzer	-	C(.01)	A(.05), C(.001)	A(.01), B(.10) C(.05), D(.01)
Helicopter		-		D(.01)
Truck	D(.10)		-	B(.10), D(.01)
Tank				-

Table 6 shows scenes in which targets listed in Column 1 take longer to find than targets in Columns 2 through 5 (significance level shown in parenthesis).

Table 6 shows the order of difficulty among targets (from hardest to easiest to find) is 1) howitzer, 2) helicopter, 3) truck, and 4) tank. In Scene D the truck was harder than the howitzer (.10 level), but in two other scenes (A at the .01 level and C at the .001 level) the howitzer was harder. Of 24 comparisons summarized in Table 6, 11 were significant (one at the .001 level, four at the .01 level, three at the .05 level, and three at the .10 level).

DISRUPTOR VARIABLES

Color

In the Virginia, Minnesota Fall, and Nebraska scenes (A, B, and D respectively), it was possible to investigate the effectiveness of the different disruptor colors for a few combinations of target and disruptor size, number, and location. The result of comparing disruptor colors are shown in Table 7.

Of the 47 comparisons shown in Table 7, 13 are significant, but only three of these at the .05 or .01 levels.

In Scene A there were 18 comparisons, only one of which was significant; that was at the .10 level. For Scene B, 11 comparisons were made. In two of these 11 comparisons, disruptor color D was more effective than color A (at the .01 and .10 levels), and in another two, D was more effective

Table 7. Comparisons Between Disruptor Colors Showing More Effective Color Where Differences Are Significant

		Comparison Between Disruptor Colors					
		A and B		A and D		B and D	
Scene	Target	Condition	Effective Color	Condition	Effective Color	Condition	Effective Color
A	1	16-1-1	-----	16-2-1 25-1-1	----- A(<.10)		
	2	16-4-1 25-2-1 38-1-1	----- ----- -----	16-4-1 25-2-1 38-1-1	----- ----- -----	16-4-1 25-2-1 38-1-1	----- ----- -----
	3	16-2-1 25-1-1	----- -----			16-1-1	-----
	4			16-1-1	-----	16-2-1 25-1-1	----- -----
B	1	16-4-1 25-2-1 38-1-1	----- ----- -----	16-4-1 25-2-1 38-1-1	----- D(<.01) D(<.10)	16-4-1 25-2-1 38-1-1	----- D(<.01) D(<.10)
	2			25-2-1	-----		
	4	16-4-1	-----				
D	1	16-2-1 25-1-1	A(<.10) B(<.10)			16-1-1	-----
	2	16-1-1	-----	16-2-1 25-1-1	A(<.10) D(<.10)		
	3			16-1-1	D(<.10)	16-2-1 25-1-1	D(<.05) -----
	4	16-4-1 25-2-1 38-1-1	----- ----- -----	16-4-1 25-2-1 38-1-1	----- ----- -----	16-4-1 25-2-1 38-1-1	D(<.10) D(<.10) -----

than B (also at the .01 and .10 levels). In scene D, where there were 18 comparisons possible, eight were significant though only at the .10 level for seven and .05 level for one. These comparisons proved to give contradictory results for the comparisons between disruptor colors A and B, and between colors A and D. When colors B and D were compared, the evidence suggested D was better.

The disruptor color comparisons do not provide clear recommendations. This is because many of the comparison conditions were not particularly effective as camouflage.

Size

It was possible to compare the effectiveness of different disruptor sizes for several combinations of target, disruptor color, number, and location in all four basic scenes. The results of this comparison are shown in Table 8.

Eighty comparisons were made for Table 8. Fourteen of these were significant; two at the .01 level, four at the .05 level, and eight at the .10 level.

Of 22 comparisons between sizes 38 and 16, five were significant. In four cases the larger disruptor was more effective (two at .01, two at .10), and in one case the smaller was more effective (.10 level). There were 25 comparisons between sizes 38 and 16. Of these only three were significant: two showing the larger size as better (both at the .05 level) and one the smaller size as better (.01 level). With the 33 comparisons

Table 8. Comparisons Between Disruptor Sizes Showing More Effective Size Where Differences Are Significant

		Comparison Between Disruptor Sizes					
		38 and 16		38 and 25		25 and 16	
Scene	Target	Condition	Effective Size	Condition	Effective Size	Condition	Effective Size
A	1	A-1-1	16, <.10	A-1-1	-----	A-1-1	-----
		A-1-2	-----	A-1-2	25,<.10	A-1-2	-----
		A-1-3	-----	A-1-3	-----	A-1-3	-----
		A-2-1	-----	A-2-1	-----	A-2-1	-----
						A-2-2	-----
						A-2-3	-----
	3	B-1-1	-----	B-1-1	-----	B-1-1	-----
						B-2-1	-----
	4	D-1-1	-----	D-1-1	-----	D-1-1	-----
		D-2-1	-----	D-2-1	-----	D-2-1	25,<.10
B	2	A-1-1	-----	A-1-1	-----	A-1-1	-----
		A-1-2	-----	A-1-2	-----	A-1-2	-----
				A-1-3	-----		
		A-2-1	-----	A-2-1	-----	A-2-1	-----
						A-2-2	-----
						A-2-3	-----
	3	A-1-1	-----	A-1-1	-----	A-1-1	-----
						A-2-1	-----
	4	A-1-1	-----	A-1-1	-----	A-1-1	-----
				A-1-2	-----		
				A-1-3	-----		
		A-2-1	38, <.01	A-2-1	38,< .05	A-2-1	25,<.05
						A-2-2	-----
						A-2-3	16,<.10
C	4	A-1-1	-----	A-1-1	-----	A-1-1	-----
		A-2-1	-----	A-2-1	-----	A-2-1	-----
D	1	B-1-1	-----	B-1-1	-----	B-1-1	-----
		B-2-1	38, <.10	B-2-1	-----	B-2-1	-----
	2	A-1-1	-----	A-1-1	-----	A-1-1	-----
		A-2-1	-----	A-2-1	-----	A-2-1	16,<.10
	3	D-1-1	38, <.01	D-1-1	-----	D-1-1	16,<.05
		D-1-2	-----	D-1-2	38, <.05	D-1-2	25,<.10
		D-1-3	38, <.10	D-1-3	-----	D-1-3	-----
						D-2-1	-----
						D-2-2	-----
						D-2-3	-----

between sizes 25 and 16, there were six significant differences. Three suggested the larger was more effective (one at .05 level, two at .10), three the smaller (also one at .05, two at .10) more effective.

There was a tendency for disruptor size increases to be associated with longer search times, but the evidence does not allow a stronger statement than that.

Number

We planned to investigate the effect of the number of disruptors in two ways. First we would investigate what happened as the number increased from one to two to four. Since we would also be varying area covered, the investigation was also intended to compare a disruptor of one size with two others that were half that size and with four that were a quarter that size. However, the eventual disruptor sizes were 16, 25 and 38 percent of the tank size, and the second comparison was not possible.

Table 9 shows the effect of increasing the number of disruptors for various combinations of background scene, target, disruptor color, size, and location.

Sixty-nine comparisons were made in Table 9. Of these, 34 were significant (two at the .001 level, five at the .01 level, 10 at the .05 level, and 17 at the .10 level). The larger number of disruptors was found to be more effective in 29 of these 34 cases. When four disruptors were compared with one, the former resulted in longer search times seven out of 10 times. When four were compared with two, longer search times

Table 9. Comparisons Between Number of Disruptors Used, Showing More Effective Number Where Differences Are Significant

		Comparison Between Disruptor Numbers					
		4 and 1		4 and 2		2 and 1	
Scene	Target	Condition	Effective Number	Condition	Effective Number	Condition	Effective Number
A	1	A-16-1	-----	A-16-1	4,<.10	A-16-1	-----
		A-16-2	-----	A-16-2	4,<.10	A-16-2	-----
		A-16-3	4,<.05	A-16-3	4,<.10	A-16-3	-----
						A-25-1	2,<.10
						A-25-2	-----
						A-25-3	-----
						A-38-1	-----
						A-38-2	2,<.10
						A-38-3	2,<.10
	3					B-16-1	2,<.10
						B-25-1	2,<.01
	4	D-16-1	4,<.10	D-16-1	4,<.10	D-16-1	-----
						D-25-1	2,<.01
						D-38-1	-----
B	2	A-16-1	4,<.001	A-16-1	4,<.001	A-16-1	-----
		A-16-2	4,<.05	A-16-2	-----	A-16-2	2,<.05
				A-16-3	-----		
						A-25-1	1,<.05
						A-25-2	2,<.01
						A-25-3	-----
						A-38-1	-----
						A-38-2	-----
						A-38-3	-----
	3					A-16-1	-----
						A-25-1	-----
	4	A-16-1	-----	A-16-1	-----	A-16-1	1,<.10
				A-16-2	-----		
				A-16-3	-----		
						A-25-1	2,<.10
						A-25-2	-----
						A-25-3	1,<.10
						A-38-1	2,<.05
						A-38-2	2,<.10
						A-38-3	-----
C	4	A-16-1	4,<.10	A-16-1	-----	A-16-1	2<.10
						A-25-1	-----
						A-38-1	-----
D	1	B-16-1	4,<.10	B-16-1	4<.05	B-16-1	1,<.05
						B-25-1	1,<.01
						B-38-1	-----
	2	A-16-1	4,<.01	A-16-1	-----	A-16-1	2,<.05
						A-25-1	-----
						A-38-1	-----
	3					D-16-1	-----
						D-16-2	2,<.05
						D-16-3	2,<.10
						D-25-1	2,<.05
						D-25-2	-----
						D-25-3	-----

occurred six times out of 11 for the four disruptor cases. Two disruptors were compared with one in 46 cases. For 16 of these, two disruptors were more effective; for five, one was more effective while for the remaining 25 comparisons the differences were not significant. An increase in the number of disruptors is clearly effective in increasing search.

Location

The effects of disruptor location were investigated in a limited way. It was investigated for each target in one scene only and with one disruptor color only. The results of these comparisons are shown in Table 10.

Of 55 comparisons in Table 10, 12 showed significant differences; three at the .01 level, four at the .05 level, and five at the .10 level. For targets 1 (helicopter) and 4 (tank), the location of one or two disruptors seems to have had little effect. There is an indication that one location (1) may have been better for target 2 (tank) with one disruptor, and that a pair of locations (1 and 3) may have been better with two. For the howitzer, although more of the significant differences occur here, they are contradictory and no clear pattern emerges.

HIDDEN FIGURES TEST

The short form of Witkin's embedded figures test was included in our test battery. This was to find out whether search time was related to performance on this test. There were 258 observers divided into 23 groups of 10, one group of 13 (three additional observers were added to this group as they had already been scheduled) and three groups of five. All the members of each group saw the same test imagery.

As our measure of performance on the hidden figures test, the mean time per item for each observer was used. The observers were then ranked within their groups on the basis of this score.

Table 10. Comparisons Between Disruptor Locations, Showing More Effective Locations Where Differences Are Significant

				Disruptor Number					
				1			2		
				Location			Location		
Target	Scene	Disruptor Color	Disruptor Color	1 v 2	1 v 3	2 v 3	1&2v 1&3	1&3v 2&3	1&3v 2&3
1	A	A	16	---	---	---	---	---	---
			25	---	---	2,<1.0	---	---	---
			38	---	---	---			
2	B	A	16	---			1&3, <.01	2&3 <.05	---
			25	1,<.01	---	---	1&3, <.10	---	---
			38	---	---	---			
3	D	D	16	1,<.01	1,<.05	3,<.05	---	---	---
			25	2,<.10	3,<.10	---	1&3, <.05	---	---
			38	---	---	---			
4	B	A	16				---	---	---
			25	---	---	---	---	1&3, <.10	---
			38	---	---	---			

The observers were also ranked within their groups on their search times for each of the eight test slides they searched. The ranks of each observer for these eight slides were summed; the final ranking was on the basis of these sums.

To compare rankings for the hidden figures test with search performance, the Spearman rank correlation coefficient was used. The results are summarized in Table 11.

Table 11. Values of Spearman's Rank Correlation Coefficient r_s

Group	N	r_s	p	Group	N	r_s	p
1	10	-.24	---	16	10	-.02	---
2	10	.12	---	17	10	.50	---
3	10	.25	---	18	10	-.02	---
4	10	-.03	---	19	10	.66	<.05
5	10	.09	---	20	10	-.37	---
6	10	.09	---	21	10	.27	---
7	10	.65	<.05	22	10	.56	---
8	10	.35	---	23	13	.05	---
9	10	-.19	---	24	10	.72	<.05
10	10	.25	---	25	5	.75	---
11	10	.39	---	26	5	.70	---
12	10	.14	---	27	5	.60	---
13	10	.10	---				
14	10	.69	<.05				
15	10	.33	---				

Table 11 shows values for 27 groups of observers tested on visual search task and hidden figures test.

As Table 11 shows, Four of the correlations were significant for groups

7, 14, 19, and 24 (all at the .05 level). Most of the remaining correlations were very low. These four groups were examined to see why they gave significant correlations; no explanation could be found.

The correlation was not a function of the sexes of the observers tested (there were two females and eight males in group 7, five of each sex in group 4, seven females and three males in group 19, and eight females and two males in group 23). The correlation was not related to the experimenter used, the location in which the experiment was carried out, or the two sets of apparatus used. It was not related to the number of significantly difficult camouflage treatments presented in the set of eight test slides, nor was it related to the number of uncamouflaged targets. It was not related to the number of observers failing at least one hidden figure in the 3-minute time period or to the total number missed by a group. The correlations remain unexplained.

With 23 of the 27 correlations being too small to reach statistical significance, it must be concluded that performance on the hidden figures test is not correlated with search performance for the task presented in this study.

OCULOMETER DATA

A second experiment was carried out using an oculometer to monitor the eye movements of the observers. Twenty-four observers were divided into four groups of six. Each group was shown eight pictures. In all, 32 scenes were used. Of these, 16 had uncamouflaged targets. The remaining 16 were selected from the more successful camouflage treatments. The selected treatments are shown in Table 12.

Table 12. Camouflaged Treatments Used in Oculometer Experiment

Scene A:

Target	Disruptor			
	Color	Size	No.	Loc.
1	A	16	4	1
2	A	16	4	1
3	B	16	2	1
4	D	25	2	1

Scene B:

Target	Disruptor			
	Color	Size	No.	Loc.
1	A	16	4	1
2	A	16	4	1
3	A	25	2	1
4	A	38	2	1

Scene C:

1	D	16	4	1
2	C	16	4	1
3	A	16	2	1
4	A	16	4	1

Scene D:

1	B	16	4	1
2	A	16	4	1
3	D	38	1	1
4	D	16	4	1

The oculometer samples eye position every 1/50 second. When there were four (or more) consecutive samples in which eye position remained within a distance of 5/90 of the display dimensions from the position in the sample under consideration, the complete sequence of five (or more) samples were treated as a single fixation.

This procedure may lead us to classify several consecutive, but distinct fixations, all made in the same general area, as a single fixation. Such a classification will affect our estimates of number of fixations, duration

of fixations and interfixational distance. Where targets are particularly difficult to find, as they are in some of our more successful camouflage treatments, there will probably be more fixations falling on likely target areas. If a series of fixations of this type are treated as a single fixation, three things will occur. First, the number of fixations will be underestimated. Second, the effect shown by Bloomfield and Howarth (1969) and Bloomfield (1970), (that average fixation time increases with target difficulty) will be exaggerated. Third, because the small sacadic distances between these proximal fixations will be ignored, the average sacadic distance computed for difficult targets is likely to be greater than it should be. This will be contrary to the expected effect that sacadic distance decreases with increases in target difficulty.

In order to compare eye position data obtained with uncamouflaged and camouflaged targets, the area of the four background scenes was divided into 36 subsections, each $4^{o}34'$ square. The percentage of the total fixation time of the six observers in each group that was spent in each of the subsections was computed for each of the 32 slides used. The results of this computation are shown in Tables 13, 14, 15, and 16.

These tables should be used in conjunction with Table 17. This lists geometric mean search time, the number of failures to detect a target (either because there was a false detection or no response was made during the 90 seconds allowed), the average fixation duration, and average sacadic distance.

Table 13. Percentage of Total Fixation Time Spent in Each Subsection of Scene A for All Four Targets with and Without Camouflage - Target Position Indicated by +

Scene A: Virginia

Uncamouflaged

Target 1: Helicopter

-	-	-	-	42.5	-
-	-	-	-	-	-
-	-	7.7	6.9	6.0	+ 31.8
-	3.0	-	-	-	2.1
-	-	-	-	-	-
-	-	-	-	-	-

Target 2: Tank

-	7.0	-	6.0	-	-
-	-	-	-	5.1	-
-	-	1.4	2.8	17.7	+ 60.0
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

-	-	-	-	-	5.0
-	19.9	-	-	12.4	-
-	-	-	8.1	7.5	+ 20.5
4.4	-	3.7	13.1	-	-
-	-	5.6	-	-	-
-	-	-	-	-	-

Target 4: Truck

-	-	-	4.1	-	-
-	16.9	-	-	-	-
-	-	8.1	-	+ 61.6	9.3
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Camouflaged

Target 1: Helicopter

0.6	1.4	-	3.0	0.6	3.3
1.3	-	3.9	1.7	0.7	-
1.0	2.0	1.3	2.0	19.4	+ 11.8
2.0	1.6	1.2	0.7	7.9	0.5
1.4	0.7	-	4.4	18.1	-
1.8	1.8	1.0	-	3.4	-

Target 2: Tank

-	-	-	-	-	-
-	-	-	-	-	-
-	-	13.8	7.1	-	+ 75.2
-	-	-	3.8	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

2.1	3.0	-	1.6	12.5	21.4
-	1.0	5.5	-	-	-
-	-	2.3	5.6	4.4	+ 3.4
-	-	2.1	15.9	1.0	-
-	0.3	1.2	0.4	12.4	0.4
-	1.2	0.4	-	-	1.8

Target 4: Truck

-	-	-	-	-	-
-	-	-	-	-	-
-	3.8	4.4	21.9	+ 48.1	10.0
-	-	-	-	11.9	-
-	-	-	-	-	-
-	-	-	-	-	-

Table 14. Percentage of Total Fixation Time Spent in Each Subsection of Scene B for All Four Targets with and Without Camouflage - Target Position Indicated by +

Scene B: Minnesota Fall

Uncamouflaged

Target 1: Helicopter

-	-	-	6.9	-	-
-	33.3 +	6.5	11.5	-	-
-	-	3.1	-	0.5	-
7.5	2.5	4.6	-	1.1	-
-	2.5	1.3	-	4.0	3.1
0.7	8.9	-	-	1.9	-

Target 2: Tank

-	-	-	4.2	-	1.7
-	23.6 +	36.9	13.5	0.7	-
-	-	10.3	3.0	4.7	-
-	-	-	-	1.5	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

1.5	0.5	2.7	5.5	2.3	0.8
1.2	4.2 +	14.0	2.3	-	-
1.8	6.2	11.0	2.2	1.2	2.8
0.6	8.1	4.2	0.8	0.5	1.4
1.7	8.6	1.1	-	2.4	1.5
1.0	-	6.9	0.7	0.6	-

Target 4: Truck

-	1.3	3.4	5.2	-	-
-	- +	31.4	2.1	-	-
-	-	9.2	10.0	14.7	1.3
-	1.9	1.5	-	-	1.3
-	2.3	2.1	-	-	-
-	-	2.5	-	7.3	2.5

Camouflaged

Target 1: Helicopter

0.9	5.4	0.7	5.9	1.3	0.9
3.7	10.2 +	3.4	2.7	1.4	0.4
7.7	6.3	6.7	6.0	0.3	0.6
5.5	3.3	2.2	2.3	1.4	1.8
2.1	2.6	3.5	1.6	0.9	1.7
0.8	0.5	2.1	1.3	1.7	0.3

Target 2: Tank

0.5	0.6	2.7	2.8	2.1	1.8
0.9	5.7 +	23.1	3.7	2.3	1.4
1.1	6.8	6.9	7.6	0.7	0.9
1.7	3.8	1.0	1.4	0.8	1.4
0.5	4.3	2.5	1.8	0.8	1.9
0.8	0.2	3.0	0.5	0.9	1.1

Target 3: Howitzer

1.5	0.4	2.3	1.9	3.7	2.0
0.9	1.7 +	4.4	0.6	5.7	0.7
6.7	5.8	3.8	4.5	-	1.0
8.4	10.2	1.4	1.6	1.4	0.7
1.5	4.1	5.3	1.4	1.0	2.2
2.2	3.1	6.1	0.2	1.3	0.4

Target 4: Truck

0.5	1.5	2.0	1.6	3.0	-
2.8	13.7 +	17.7	3.4	2.1	-
0.3	0.4	7.3	8.5	1.0	1.1
3.1	14.2	1.7	0.6	-	-
2.9	0.8	5.5	0.6	1.0	-
0.7	0.7	0.9	0.3	0.3	-

Table 15. Percentage of Total Fixation Time Spent in Each Subsection of Scene C for All Four Targets with and Without Camouflage - Target Position Indicated by +

Scene C: Minnesota Winter

Uncamouflaged

Target 1: Helicopter

-	-	5.4	-	-	-
-	9.5	2.7	-	-	-
-	-	-	-	-	-
11.6	51.1	+ 15.0	-	-	-
-	-	-	-	-	4.8
-	-	-	-	-	-

Target 2: Tank

5.4	1.6	3.1	6.2	-	2.3
-	3.5	12.4	1.9	-	-
9.1	4.3	9.9 +	9.1	-	2.3
-	8.6	10.5	-	3.5	-
-	-	2.1	-	1.2	-
-	-	2.9	-	-	-

Target 3: Howitzer

-	9.2	-	0.9	1.0	-
5.0	12.9	2.4	2.0	3.0	-
0.7	2.6	1.0	-	1.9	-
1.2	1.9	+ 46.7	2.4	-	0.3
-	-	-	1.5	-	0.3
2.3	-	1.0	-	-	-

Target 4: Truck

-	-	-	-	-	-
-	-	-	-	-	-
2.6	-	-	-	-	-
-	74.8	+ 22.6	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Camouflaged

Target 1: Helicopter

-	0.9	0.9	6.4	10.1	-
-	27.6	-	7.4	-	1.8
-	-	5.5	1.8	-	-
-	1.8	+ 24.2	-	-	-
-	-	3.4	-	-	-
-	-	4.9	-	3.1	-

Target 2: Tank

-	-	-	-	4.9	-
-	-	-	10.4	11.5	-
-	54.3 +	-	-	-	-
-	14.2	4.9	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

0.6	1.1	0.7	1.8	5.1	2.7
2.0	0.9	3.0	1.3	6.4	1.6
1.4	2.1	1.3	2.3	0.7	2.1
3.9	1.3	+ 21.8	2.9	4.3	1.7
2.4	1.5	3.1	2.6	5.0	3.2
2.6	1.5	1.7	0.1	2.8	0.9

Target 4: Truck

-	-	-	-	-	-
-	-	5.0	-	-	-
-	-	11.4	-	-	-
-	-	+ 68.4	-	-	-
15.2	-	-	-	-	-
-	-	-	-	-	-

Table 16. Percentage of Total Fixation Time Spent in Each Subsection of Scene D for All Four Targets with and Without Camouflage - Target Position Indicated by +

Scene D: Nebraska

Uncamouflaged

Target 1: Helicopter

-	-	-	-	-	-
-	2.1	-	-	-	-
-	-	-	-	-	-
-	69.3	28.6	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 2: Tank

-	5.9	13.1	-	-	-
-	-	3.1	6.2	-	-
7.6	-	58.9	-	-	-
3.1	2.4	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

-	14.7	-	3.6	-	-
-	-	1.4	-	3.2	3.6
3.6	-	25.7	-	-	-
-	14.7	26.4	-	-	-
-	3.2	-	-	-	-
-	-	-	-	-	-

Target 4: Truck

-	2.5	6.8	0.7	4.4	6.1
-	0.3	-	-	0.5	-
1.7	31.4	16.2	6.4	-	-
1.7	8.3	-	1.1	-	-
1.0	6.5	-	-	-	-
3.3	0.9	-	-	-	-

Camouflaged

Target 1: Helicopter

2.3	4.2	-	-	-	-
-	2.8	6.1	20.5	4.2	-
-	22.8	24.2	1.4	-	-
-	11.6	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Target 2: Tank

1.0	4.3	12.8	21.3	3.0	-
-	-	5.8	-	-	8.3
-	3.3	1.8	5.0	3.8	-
3.0	5.8	3.8	9.5	1.5	-
-	6.3	-	-	-	-
-	-	-	-	-	-

Target 3: Howitzer

6.5	8.0	2.0	2.3	2.2	3.3
-	-	16.7	1.7	3.2	2.5
-	2.7	2.3	5.5	-	-
-	25.6	5.7	-	-	-
5.0	-	-	-	-	-
1.3	3.7	-	-	-	-

Target 4: Truck

1.6	6.3	-	-	-	-
-	-	13.1	-	-	-
2.1	23.6	44.8	-	-	-
7.9	-	0.5	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Table 17. Geometric Mean Search Time, Failures to Detect Target, Average Fixation Duration and Average Sacadic Distance for Camouflaged and Uncamouflaged Targets in Oculometer Experiment

		Scenes															
		A				B				C				D			
Target	CorU	Mean	Fail.	Dur.	Dist.	Mean	Fail.	Dur.	Dist.	Mean	Fail.	Dur.	Dist.	Mean	Fail.	Dur.	Dist.
1	U	2.30	---	0.36	351	3.64	---	0.39	501	0.73	---	0.33	560	0.93	---	0.40	283
	C	4.40	---	0.31	432	13.76	UD	0.49	427	0.73	---	0.28	432	1.52	1F	0.29	495
2	U	1.21	---	0.33	404	1.79	---	0.41	397	0.71	---	0.32	515	1.54	---	0.31	366
	C	1.63	1F	0.47	248	17.22	UD	0.54	415	1.41	---	0.49	319	1.16	---	0.33	516
3	U	2.18	---	0.25	621	6.88	---	0.31	436	3.17	---	0.40	440	1.68	---	0.27	468
	C	4.39	---	0.36	434	17.27	2F	0.56	448	10.47	UD	0.43	412	4.63	---	0.34	522
4	U	1.04	---	0.34	697	2.69	---	0.34	404	1.12	---	0.46	213	5.34	---	0.43	487
	C	1.17	---	0.29	361	10.76	1F	0.57	398	1.06	---	0.26	383	2.09	---	0.82	381

<u>Key</u>

Targets:

1 = Helicopter
2 = Tank
3 = Howitzer
4 = Truck
C = Camouflaged
U = Uncamouflaged

Mean = Geometric Mean Search Time
Fail. = Failures
F = False Alarm
UD = Not detected within 90 seconds
Dur. = Average Fixation Duration (seconds)
Dist. = Average Sacadic Distance (minutes of arc)

Table 13 deals with the Virginia scene. It shows that for the helicopter and the howitzer, the use of disruptive camouflage causes a much greater coverage of the scene. This effect was not noticable for the tank and the truck. The camouflaged condition chosen for the tank had, in the main experiment, produced a relatively high search time, but the increase had not been significant. Because of this, it is not surprising that there was no discernable change in eye movement pattern. The camouflage used for the truck had produced a significant shift in search time distribution in the main experiment: however, the search times obtained here for both camouflaged and uncamouflaged targets were very small.

Table 14 shows that there was a much wider coverage of the Minnesota Fall scene for all four targets. The four camouflaged treatments had proved effective before and, as Table 17 shows, all produced large shifts in search time in this experiment.

In the Minnesota Winter scene, the search times were small for all targets except the howitzer, regardless of whether camouflage was added. In addition,the camouflage used with the helicopter had not significantly increased search time. Table 15 shows that with the addition of camouflage there is an increase in coverage for the howitzer and, surprisingly, for the helicopter. There seems to be no essential change for the truck, while the tank had more coverage for the camouflaged condition.

For the Nebraska scene (Table 16), there appears to be wider coverage for the helicopter, tank and howitzer when camouflage is used. For the tank, this coverage was surprising since search time was not correspondingly increased. Again, the truck does not follow the pattern. In fact, it re-

verses it, as the tank had done in the Minnesota Winter scene. It should be noted that the camouflage used for the truck did not result in significantly increased search times in the main experiment. Also, there was a decrease in time for the camouflage condition used here.

Overall, there are eight target-scene combinations with large increases in time when camouflage is added. These are the helicopter in the Virginia and Minnesota Fall scenes, the howitzer in all four scenes, and the tank and the truck in the Minnesota Fall scene. All eight of these combinations also have shifts in eye movement pattern with the coverage for the camouflaged conditions being dispersed more over the display.

Three other combinations (the helicopter in the Minnesota Winter and Nebraska scenes, and the tank in the Nebraska scene) in which there is little difference in search time, also show a similar spreading effect. Of the other five combinations, where little search time difference occurred, three (tank in Virginia, and truck in Virginia and Minnesota Winter scenes) have no real change in eye movement pattern. With the remaining two (tank in Minnesota Winter and truck in Nebraska scenes) there is a broader coverage in the uncamouflaged condition.

Table 17 provides information on fixation duration and sacadic distance. Of the eight combinations of target and scene where camouflage increased search time, seven showed increases in fixation duration. This increase was expected, both because of previous work and because of the way fixations were defined here. At the same time for five of these eight there was an increase in sacadic distance. This was against expectations, but

may have occurred because of our definition of fixation. Of the other eight combinations where there was little effect on search time of camouflage, there was an increase in fixation duration for three, and a reduction in sacadic distance for five.

SECTION 5

DISCUSSION

Of the 155 camouflage treatments tested, 46 produced shifts in search time distributions that were statistically significant. Statistical significance should be distinguished from operational significance. For example, there were camouflage treatments that led to significantly different search time distributions for the truck in both the Minnesota Winter and Fall scenes. In the Winter scene, four treatments resulted in significant increases in search time. It can be seen from Table 3 that the geometric mean search time for these conditions increased from 1.01 seconds to 1.18, 1.39, 1.19 and 1.28 seconds. None of these shifts is likely to be operationally significant. On the other hand, the one treatment that led to a statistically significant increase for this target in the Fall scene had an increase in geometric mean search time from 3.72 seconds to at least 10.74 seconds. The 10.74 seconds is an underestimate. The 10 search trials on which it is based include four false alarms, or misdetections, and one failure to detect anything. All five of these trials were included as if they had resulted in correct detections and, clearly, for that more time would have been required. Even if this was not an underestimate, it represents a substantial increase in the time required to detect this particular target. Substantial increases of this kind can be seen for all four targets in the Minnesota Fall scene and for the howitzer in all four scenes.

When comparisons were made between scenes and between targets for the uncamouflaged target pictures (Tables 4, 5 and 6), it was clear that the Minnesota Fall scene took longer to search than the other three scenes,

and that the howitzer was more difficult to find than the other targets in all scenes. This scene and this target were the most affected by the use of camouflage.

Considering those camouflage conditions that produced significant changes in search time for the helicopter, tank and truck in the Virginia, Minnesota Winter and Nebraska scenes, we find geometric mean search times that are between 117 and 150 percent of the uncamouflaged time. When these same three targets are successfully camouflaged in the Minnesota Fall scene the geometric mean search times are between 200 and 400 percent of the uncamouflaged times. For the howitzer, successful addition of camouflage produces at least 200% increases in geometric search time in all scenes. It appears that the more difficult the initial task is, the greater the effect of applying camouflage.

Three of the targets, the tank, howitzer and truck had been painted with camouflage paint. Nevertheless, their basic color, like that of the helicopter was dark green. It is probably this fact that led to them being harder to find against the green grass in the Minnesota Fall scene rather than the grey-brown of the ground in the Nebraska background.

Comparing the pictorial content of the four basic scenes and inspecting Tables 4 and 5 leads to the suggestion that there are two properties of backgrounds that are particularly important in determining the difficulty of the search task. The first relates to the mean contrast level of the ground and the foliage, the second to the variability in contrast around the mean contrast levels. The first property can be examined by comparing the Minnesota Fall and Nebraska scenes, in which there is a relatively small difference between the contrast levels of the ground and the foliage, to the

Virginia and Minnesota Winter scenes, in which there is a relatively large contrast difference. It appears that the closer the two contrast levels are to each other, the harder the search task is. The second property can be explored by comparing the Minnesota Fall scene with the Nebraska scene, and the Virginia scene with the Minnesota Winter scene. There is considerably more variability in the appearance of both the ground and foliage in the Minnesota Fall and Virginia scenes than in the two comparison backgrounds. The greater variability is associated with an increase in search times.

In summary, search appears to be more difficult when the mean contrast levels of the ground and the foliage are close in value and/or when the variability in contrast around one or both of those mean contrast levels is high.

Tables 4 and 6 show that the howitzer and the helicopter were harder to locate than the larger and more compact tank and truck. Smaller targets are, obviously, easier to hide. It is also easier to break up the outline of an elongated target with disruptors.

The analysis of disruptor color presented in Table 7 was inconclusive. However, some comments on this variable can be made. The disruptors devised for the two Minnesota backgrounds were poor, hence their very limited use in those two scenes. Interestingly, the disruptors devised for the Minnesota Fall scene were extremely effective when used with the howitzer in the Virginia scene. These disruptors had not worked well in the background scene they were intended for, probably because the lightest colors used in their color mix made them stand out somewhat against the grass on which the targets were placed. However, when used with a small target in a background that is light in color, the paleness of disruptor and ground were close enough to produce very effective camouflage.

The darker disruptor developed for the Virginia scene was used with some success, particularly with the tank, in the Minnesota Fall scene. Where the ground is relatively dark, as in the Minnesota Fall and Nebraska scenes, we suggest that the basic color used for the disruptor should be as dark as the ground color. To make it more effective it should also contain other colors that are even darker. For scenes in which the ground is relatively light, like the Virginia and Minnesota Winter backgrounds, two approaches are possible. The disruptors may be essentially colored like the foliage, as were those we developed, or they may include much lighter colors, as did our Minnesota Fall disruptors.

As far as the other disruptor variables investigated were concerned, changes in the location of disruptors did not produce a clear effect. Increasing disruptor size did lead to some increases in search time. However by far the biggest effects were obtained when the number of disruptors was increased (these effects are shown in detail in Table 9).

The most important finding of the oculometer experiment was that effective camouflage obscures the target,making it much harder to find, resulting in the observer spreading his fixations over a much wider area of the background scene. It does not merely make the identity of the target harder to decide, rather it makes it harder to detect the target at all.

There was no systematic correlation between performance on the hidden figures test and on the search task. The fact that such a correlation has been found before suggests that the particular imagery used for the search task is crucial.

RECOMMENDATIONS AND FUTURE WORK

If one wishes to lessen the probability of a particular target being detected or to slow down the detection process, this study suggests several ways in which this might be done. First, as regards to the area where the target is placed, the ground and the foliage should be relatively dark and, at the same time, both should be heterogeneous rather than bland and homogeneous. Next, if disruptors can be used, they should be dark like the ground on which the target stands. They should also contain other colors which are even darker. While a larger disruptor covers more of the target than a smaller one, a more successful approach is to use several small disruptors placed to break up the outline of the target as much as possible.

One way of extending our knowledge of disruptive camouflage techniques is to test the various suggestions made above more directly. In addition, it would be of interest to investigate the placement of targets in various backgrounds relative to the local clutter. Recent work by Monk and Brown (1975) and Bloomfield, Beckwith, Emerick and Tei (1975), shows that the effects of the density of clutter are far from understood. The latter study is particularly relevant. Bloomfield et al. showed that as the distance between a target and the nearest nontarget clutter items was reduced, the target became easier to detect, rather than harder, as one might have expected. This effect is dependent on the relationship between the discriminability of the target from its immediate background, the discriminability of the target from the nontarget clutter items, and the discriminability of the nontargets from the background. The range of situations in which this effect would occur are unknown. However, Bloomfield et al. report that increasing the separation between target and clutter items can result in search times nine times as long as those obtained when the target and clutter items are very close. Tne effect could be of great potential importance. A direct

test of the suggestions made on the basis of the current study could be combined with an investigation of target placement in relation to local clutter. This would seem to be the most efficient next step in exploring the art of concealment.

SECTION 6

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APPENDIX A

IMAGERY RECEIVED BY INDIVIDUAL GROUPS

There were 27 groups of observers. The imagery that each received is shown in Table A1. Two slides of each of the four backgrounds were presented to each group. One slide was shown in the correct orientation, the other was reversed from left to right in the projector. For the first observer in each group the order of the first four slides (one from each background) was randomized. This random order was then repeated in the second set of four slides. For the second observer, the same basic order was used except that the slide the first observer had seen first was presented at the end of the second set and all the other slides were moved forward one position, with the first slide of the second set moving to the end of the first set. For the third observer, the slide seen first by the second observer was presented last with the other slides moving forward again. This rotational procedure was used for the remaining observers in the group. In the groups with 10 observers, the order for the first and second observers was repeated for the ninth and tenth observers.

The following key should be used for Table A1.

<u>Key to Table A1</u>

N = Number of observers in group

Target: 1 = Helicopter, 2 = Tank, 3 = Howitzer, 4 = Truck

Disruptor Color: A = Dark Green, B = Light Green
C = Blue Green, D = Grey Brown

Table A1. Camouflage Conditions Presented to the 27 Groups of Observers in the Main Experiment

SCENE A: VIRGINIA

		Normal Presentation					Reversed Presentation				
		Target	Disruptor				Target	Disruptor			
Group	N		Color	Size	Number	Location		Color	Size	Number	Location
1	10	1	A	16	4	1	4	-	-	-	-
2	10	1	-	-	-	-	3	B	25	2	1
3	10	4	D	16	4	1	3	-	-	-	-
4	10	1	A	16	1	1	2	B	16	4	1
5	10	4	D	25	2	1	1	A	16	2	1
6	10	1	A	16	1	2	4	D	38	2	1
7	10	1	A	16	1	3	2	-	-	-	-
8	10	1	A	16	2	2	2	A	16	4	1
9	10	2	B	25	2	1	1	A	16	2	3
10	10	1	A	25	1	1	3	B	38	1	1
11	10	3	A	16	2	1	1	A	25	1	2
12	10	1	A	25	1	3	3	B	16	1	1
13	10	2	A	25	2	1	1	A	25	2	1
14	10	1	A	25	2	1	2	A	38	1	1
15	10	1	A	25	2	3	3	B	16	2	1
16	10	3	A	25	1	1	1	A	38	1	1
17	10	2	D	16	4	1	1	A	38	1	2
18	10	1	A	38	1	3	2	B	38	1	1
19	10	3	B	25	1	1	1	A	38	2	1
20	10	1	B	16	1	1	4	D	38	1	1
21	10	1	D	16	2	1	4	D	25	1	1
22	10	4	B	16	2	1	1	D	25	1	1
23	13	4	B	16	1	1	3	D	16	1	1
24	10	2	D	38	1	1	4	D	16	1	1
25	5	4	D	16	2	1	2	D	25	2	1
26	5	4	A	16	1	1	4	D	16	2	1
27	5	4	A	16	1	1	2	D	25	2	1

Table A1. Camouflage Conditions Presented to the 27 Groups of Observers in the Main Experiment (Continued)

SCENE B: MINNESOTA FALL

		Normal Presentation					Reversed Presentation				
		Target	Disruptor				Target	Disruptor			
Group	N		Color	Size	Number	Location		Color	Size	Number	Location
1	10	3	-	-	-	-	2	D	25	2	1
2	10	4	B	16	4	1	2	-	-	-	-
3	10	3	A	16	1	1	4	-	-	-	-
4	10	4	A	25	1	1	1	B	16	4	1
5	10	3	A	16	2	1	4	A	16	2	1
6	10	2	A	16	1	1	1	A	16	4	1
7	10	3	A	25	1	1	1	B	16	4	1
8	10	2	A	38	2	1	1	B	38	1	1
9	10	1	D	16	4	1	2	A	38	1	1
10	10	3	A	25	2	1	1	D	25	2	1
11	10	2	A	38	1	3	4	A	16	1	1
12	10	2	A	16	1	2	4	A	38	2	1
13	10	4	A	38	1	3	2	A	16	2	1
14	10	2	A	16	2	2	3	A	38	1	1
15	10	2	A	38	1	2	1	D	38	1	1
16	10	1	A	16	1	2	4	A	38	1	2
17	10	4	A	16	2	2	2	A	25	2	3
18	10	2	A	25	2	2	1	-	-	-	-
19	10	4	A	38	1	1	2	A	25	2	1
20	10	4	A	16	2	3	2	A	16	4	1
21	10	2	A	25	1	1	4	A	16	4	1
22	10	2	A	25	1	2	4	A	25	1	2
23	13	2	A	25	1	3	4	A	25	1	3
24	10	4	A	25	2	1	1	A	25	2	1
25	5	4	A	25	2	2	4	A	25	2	3
26	5	2	A	16	2	3	4	A	25	2	2
27	5	2	A	16	2	3	4	A	25	2	3

Table A1. Camouflage Conditions Presented to the 27 Groups of Observers in the Main Experiment (Continued)

SCENE C: MINNESOTA WINTER

Group	N	Normal Presentation					Reversed Presentation				
		Target	Disruptor				Target	Disruptor			
			Color	Size	Number	Location		Color	Size	Number	Location
1	10	2	-	-	-	-	4	A	16	4	1
2	10	1	D	16	4	1	4	-	-	-	-
3	10	1	-	-	-	-	2	C	16	4	1
4	10	3	A	25	2	1	4	A	16	1	1
5	10	1	A	16	1	1	4	A	16	2	1
6	10	4	A	25	1	1	2	A	16	2	1
7	10	2	A	25	1	1	4	A	25	2	1
8	10	3	-	-	-	-	4	A	38	1	1
9	10	3	A	38	1	1	4	A	32	2	1
10	10	4	A	16	4	1	2	-	-	-	-
11	10	1	-	-	-	-	2	C	16	4	1
12	10	4	-	-	-	-	1	D	16	4	1
13	10	3	A	25	2	1	4	A	16	1	1
14	10	4	A	16	2	1	1	A	16	1	1
15	10	4	A	25	1	1	2	A	16	2	1
16	10	4	A	25	2	1	2	A	25	1	1
17	10	3	-	-	-	-	4	A	38	1	1
18	10	3	A	38	1	1	4	A	38	2	1
19	10	2	-	-	-	-	4	A	16	4	1
20	10	2	A	16	2	1	3	-	-	-	-
21	10	3	A	25	2	1	2	A	25	1	1
22	10	3	A	38	1	1	4	A	38	2	1
23	13	4	-	-	-	-	1	D	16	4	1
24	10	3	A	16	2	1	4	A	16	1	1
25	5	3	A	38	1	1	1	-	-	-	-
26	5	1	A	16	1	1	3	A	38	1	1
27	5	1	-	-	-	-	1	A	16	1	1

Table A1. Camouflage Conditions Presented to the 27 Groups of Observers in the Main Experiment (Concluded)

SCENE D: NEBRASKA

Group	N	Normal Presentation					Reversed Presentation				
		Target	Disruptor				Target	Disruptor			
			Color	Size	Number	Location		Color	Size	Number	Location
1	10	3	D	25	2	1	1	-	-	-	-
2	10	3	A	16	1	1	2	A	16	4	1
3	10	2	-	-	-	-	1	B	16	4	1
4	10	2	A	16	2	1	3	D	16	2	3
5	10	2	B	16	1	1	3	D	16	1	1
6	10	3	D	16	1	2	1	D	16	1	1
7	10	4	A	38	1	1	3	B	16	2	1
8	10	4	B	16	4	1	3	D	16	3	1
9	10	4	D	25	2	1	3	D	16	2	1
10	10	2	D	25	1	1	4	D	38	1	1
11	10	4	B	38	1	1	3	B	25	1	1
12	10	3	D	16	2	2	2	A	25	2	1
13	10	1	B	38	2	1	3	D	25	1	1
14	10	3	D	25	1	2	4	A	16	4	1
15	10	3	D	25	1	3	4	D	16	4	1
16	10	2	D	16	2	1	3	D	25	2	2
17	10	1	B	25	1	1	3	D	25	2	3
18	10	4	A	25	2	1	3	A	16	1	1
19	10	1	A	16	2	1	3	D	38	1	1
20	10	4	-	-	-	-	1	A	25	1	1
21	10	4	B	25	2	1	1	B	16	1	1
22	10	2	A	16	1	1	1	B	16	2	1
23	13	1	B	25	2	1	2	A	25	1	1
24	10	1	B	38	1	1	2	A	38	1	1
25	5	2	A	38	2	1	3	D	38	1	2
26	5	3	D	38	1	3	2	A	38	2	1
27	5	3	D	38	1	2	3	D	38	1	3

APPENDIX B

INSTRUCTIONS TO OBSERVERS

In this experiment there are three different tasks. In the first, I will show you some slides of various backgrounds and ask you to locate a target of military significance in each one. Then there will be a brief vision test, followed by a hidden figures test. Finally, we will return to the first task.

VISUAL SEARCH TASK

You will be shown aerial views of the ground. There are four possible targets: a helicopter, tank, gun, and truck. [One example of each target was shown to the observer.] Only one target will be presented on each slide. The targets may be partially obscured. Respond if you are sure you see a target, even if you do not know which target it is. When a trial is about to begin, I will say "Ready," then "Go." You should then push the button. You will see a scene on the screen. Please begin looking for a target immediately. As soon as you locate one, release the button. Please respond as soon as you are sure you have found a target even if you do not know what it is.

The length of time the shutter is open will be recorded. After you have released the button, I will ask you to point to the blank screen and indicate where the target was located.

There will be only one target in each scene. Please try to find it as quickly as possible. You will be allowed up to 90 seconds to find the target. As

soon as you find the target release the button; only after that should you indicate where it is.

Are there any questions?
[After four presentations, the observer moved to the Titmus Vision Tester.]

VISION TEST

Near Acuity

Look at the large sign marked number 1, with a ring in each of its four corners. Note that three of the rings are broken and that only one is full or complete. The unbroken ring is at the right. Now look at sign number 2. Is the unbroken ring at the top, the bottom, left or right?

(This procedure continues through the signs 3, 4, 5 etc. until the observer gives two consecutive misses. The last correct score is then noted.)

Color Discrimination

You should be looking at six circles. Please read the numbers you see in them beginning with circle A, and going on through B, C, D, and E to F.
[The observer moved back to the main apparatus.]

HIDDEN FIGURES TEST

Now I am going to show you a series of slides. There will be two figures on each. A simple figure will appear on the left. A more complex figure will appear on the right. The complex figure will usually be colored.

Your task will be to search the larger more complex figure and locate the smaller simple figure in it. In every case the smaller figure will be present in the larger design. It will always be in the upright position, not rotated or reversed. There may be several of the smaller figures in the same large design, but you need only indicate one of them. Work as quickly as you possibly can, since you are being timed. Be sure that the figure you find is the same as the original figure in size and in shape. As soon as you have found the figure, trace its outline with your finger. As soon as you have completed the figure, the timer will be stopped. You have up to 3 minutes to find each figure, and you may need it.

(If figure is not found within 3 minutes, the trial is stopped and the score is recorded as 3 min (failed). For trials in which figure is found, tracing time is included in response time recorded.)

CONTINUATION OF VISUAL SEARCH TASK

Now we will go back to the first task. Again the targets are a helicopter, tank, gun and truck. Please respond as soon as you find a target even if you cannot say exactly what it is.

Are there any questions?